RF Lightwave Integrated Circuits (R-FLICS) Kick-off Meeting
August 16-17, 2000

Highly Efficient RF Lightwave Integrated Transmitters (RFLIT)

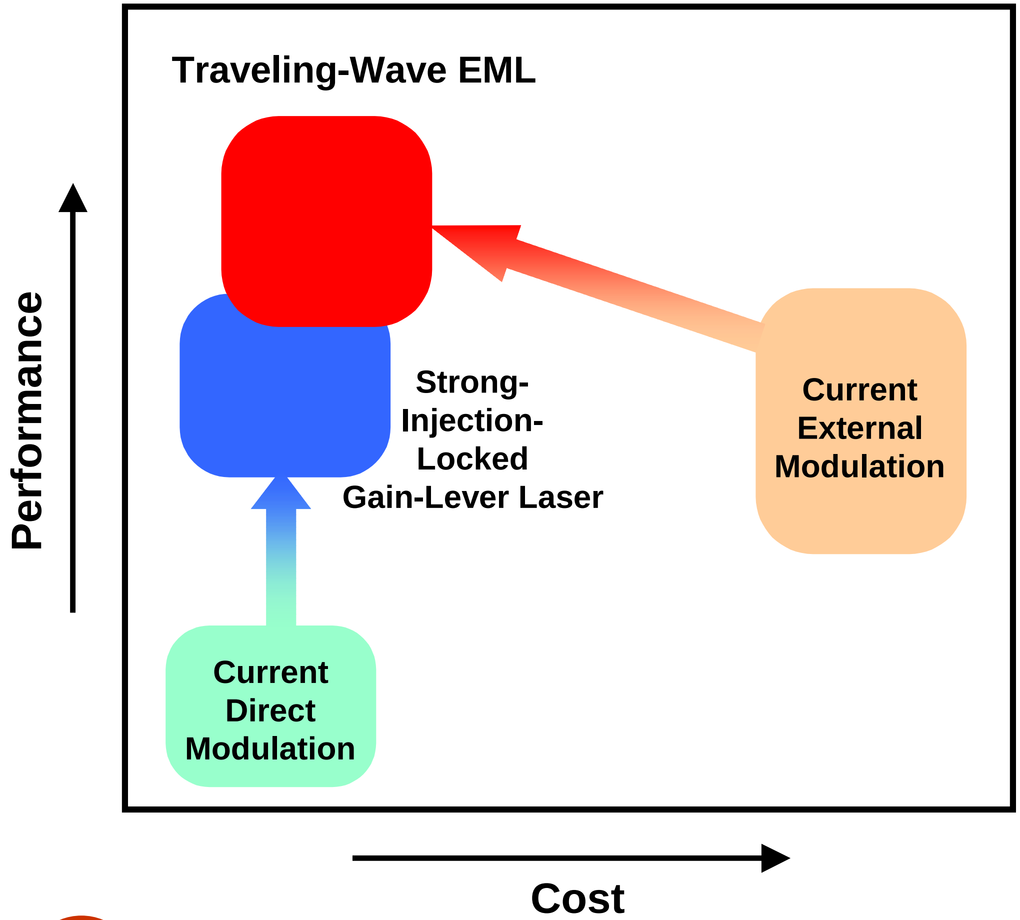
Multiplex, Inc.
UCLA
UCSD

Multiplex,Inc.
Photonics for Communications

Program Goals

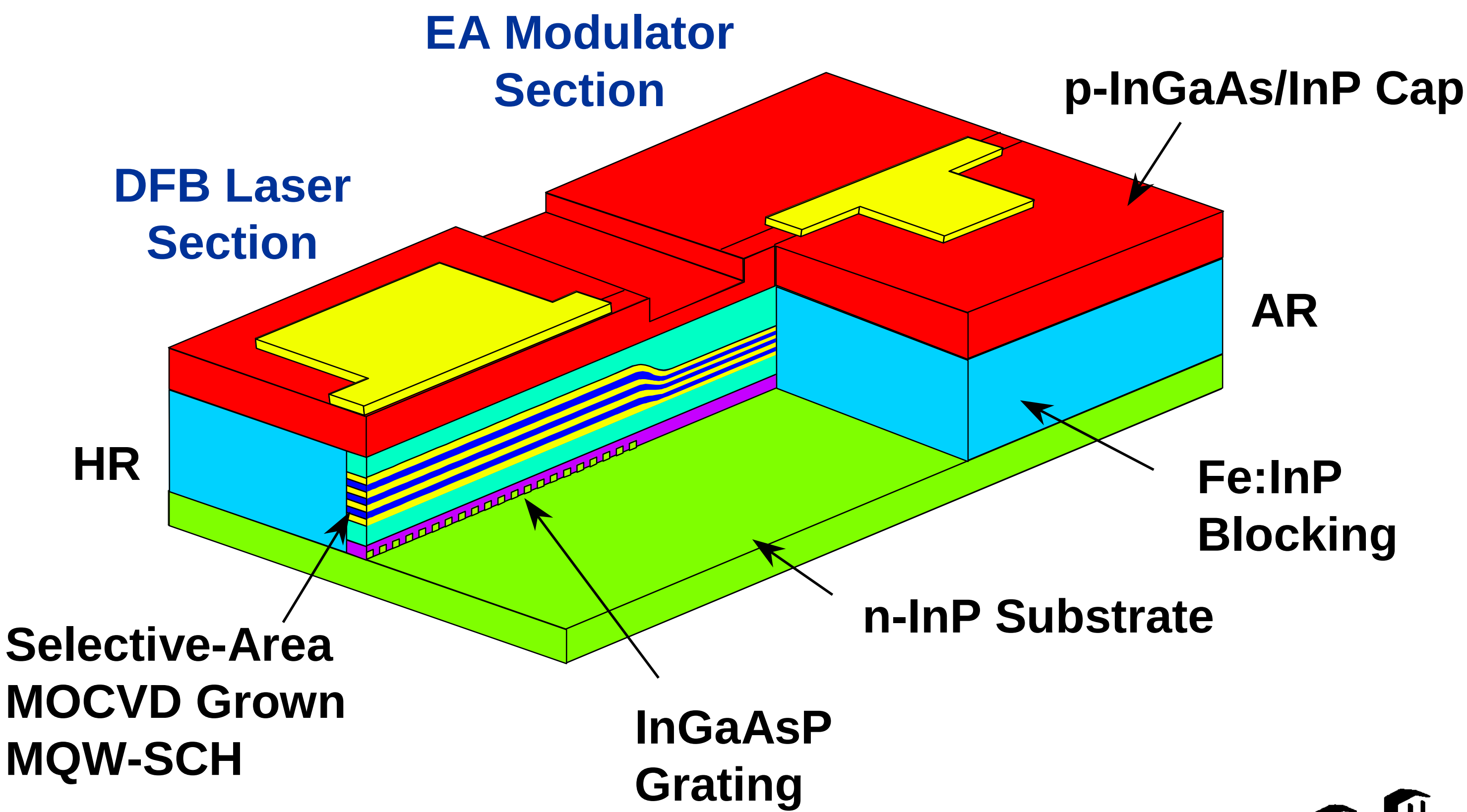
- Develop chip-scale RF Lightwave Integrated Transmitters (RFLIT) for high performance military and commercial RF systems:
  - Broadband electroabsorption-modulated lasers (EML)
  - High performance directly modulated laser with strong optical injection locking
- Leverage on commercial telecom technologies
  - Multiplex currently produces 2.5 and 10 Gbit/sec EML and tunable DFB lasers
- Significantly reduce the size, weight, power, and cost of RF Lightwave systems
- Deliver packaged parts to RFLICS partners

Objective of RF-Lightwave Integrated Transmitters (RFLIT)



Multiplex,Inc.
Photonics for Communications

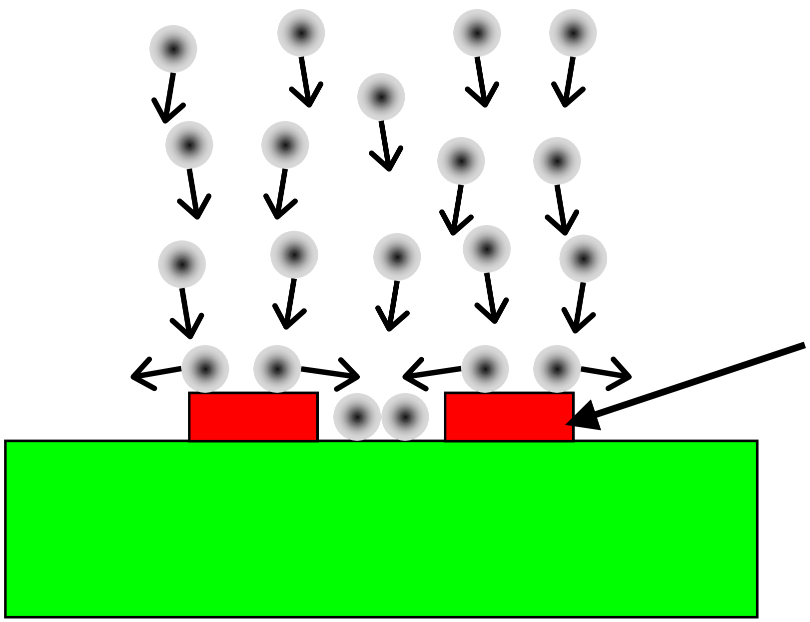
Integrated DFB Laser / EA Modulator by Selective Area Growth



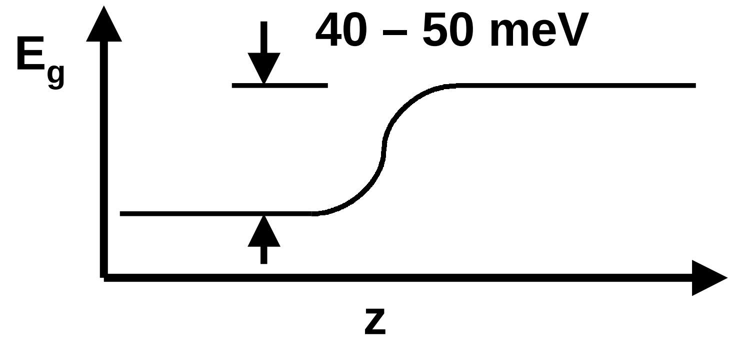
Multiplex,Inc.
Photonics for Communications

Selective-Area MOVPE Growth

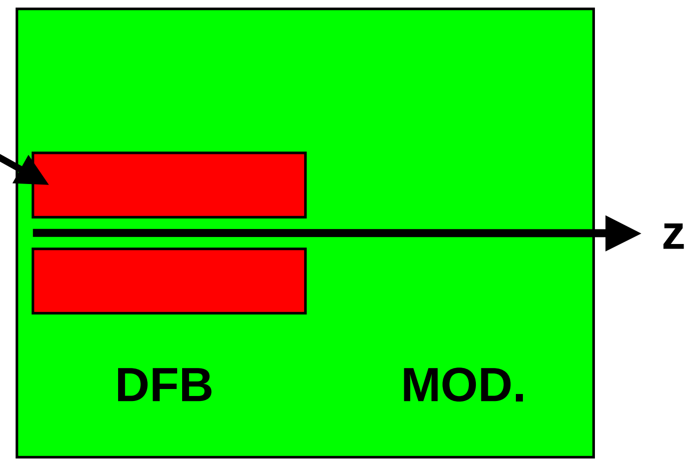
Group-III Precursors
- Vapor-phase diffusion
- Surface migration



Cross-Sectional
View During Growth



SiO_2
mask



Top View

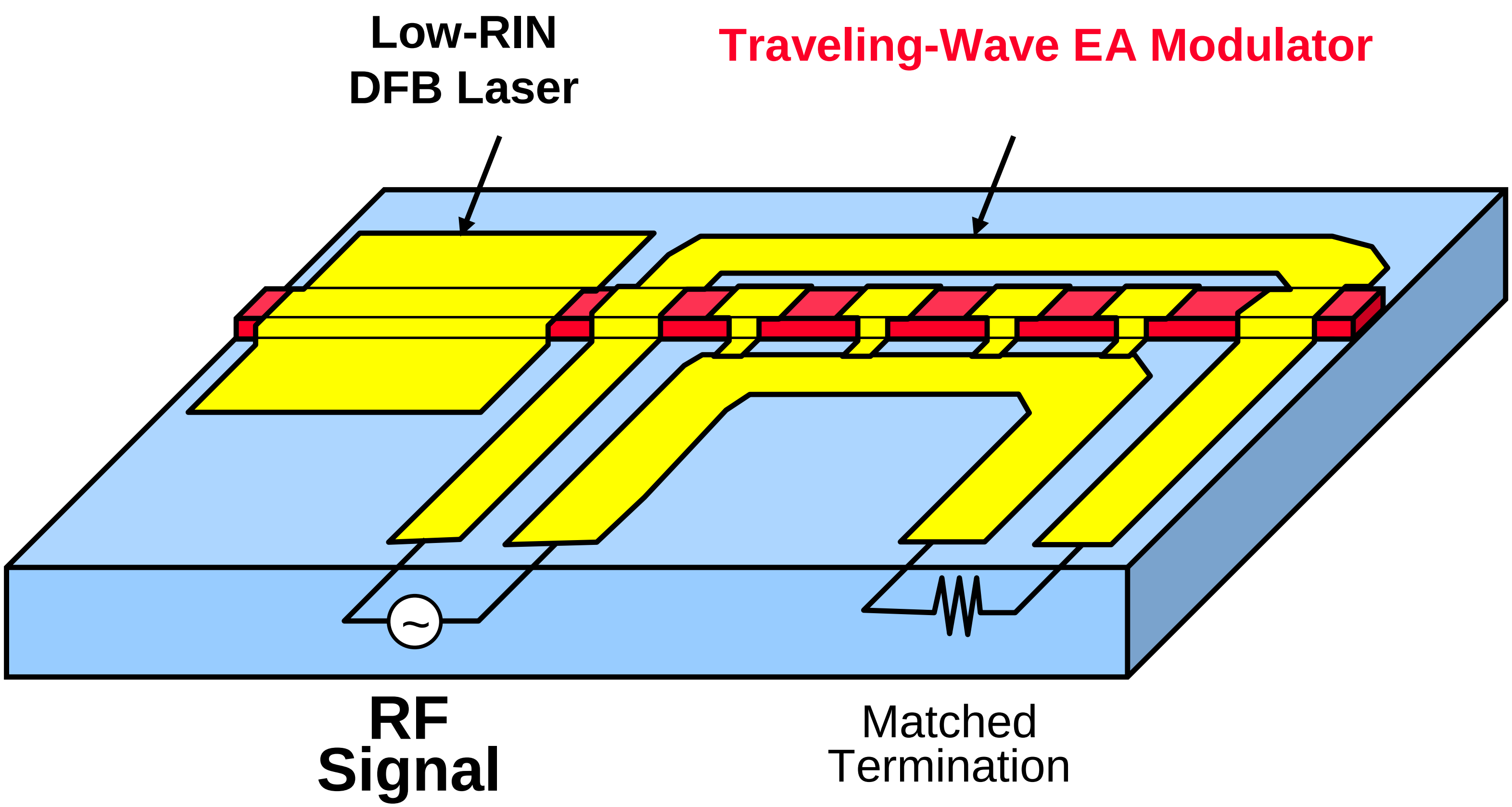
- *Our activities are built around 6 platforms,*

  - *MO-CVD Crystal growth*
  - *Processing*
  - *Packaging*
  - *System Parameter Evaluation*
  - *Logistics*
  - *Quality Assurance*

  - *Design is an integrated part in all platforms*

All directed by experts in each area. Quality program built in each platform.
We strongly believe that this can give you great benefits as our customer.

Proposed Traveling-Wave EML

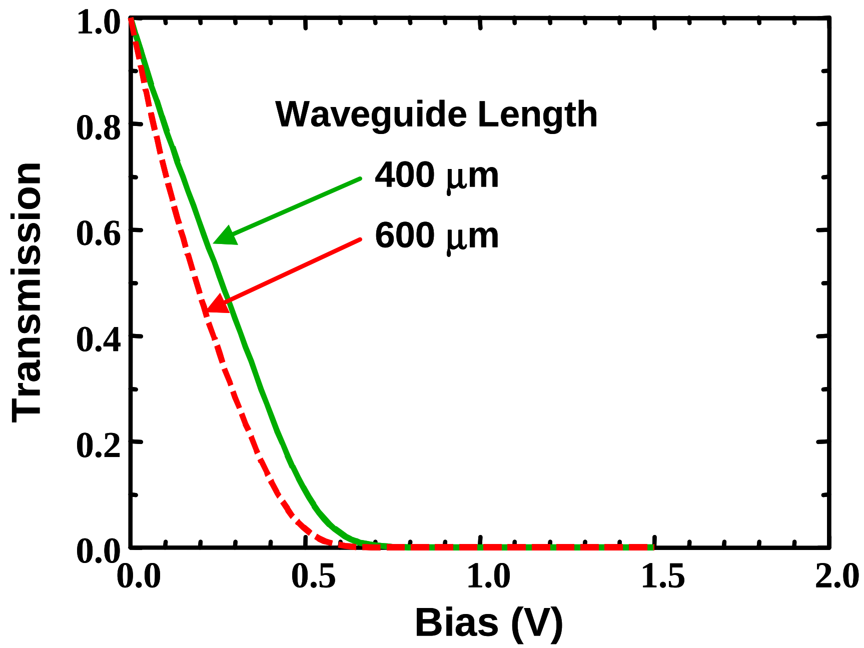


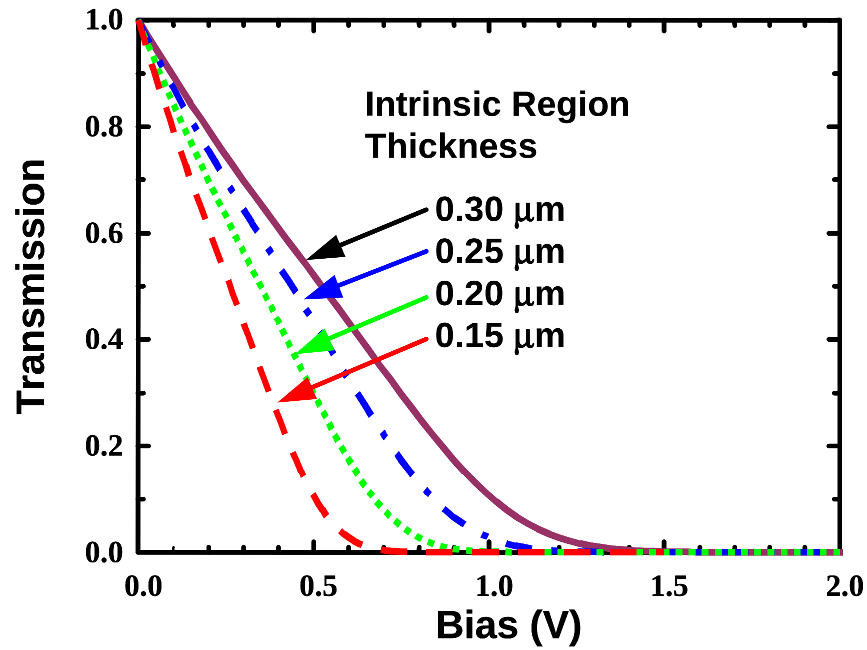
Multiplex,Inc.
Photonics for Communications

Advantages of Traveling-Wave EML

- Compact and lightweight
  - ~ 1000 X smaller than YAG lasers + $LiNbO_3$ modulators
- Low power consumption
- Broadband operation with low V_π
- Insensitive to temperature, wavelength change
- Monolithic integration → Low-cost batch fabrication
- Leverage on commercial telecommunication technology

Traveling-Wave Electroabsorption Modulators





Multiplex, Inc.
Photonics for Communications

UCLA UCSD

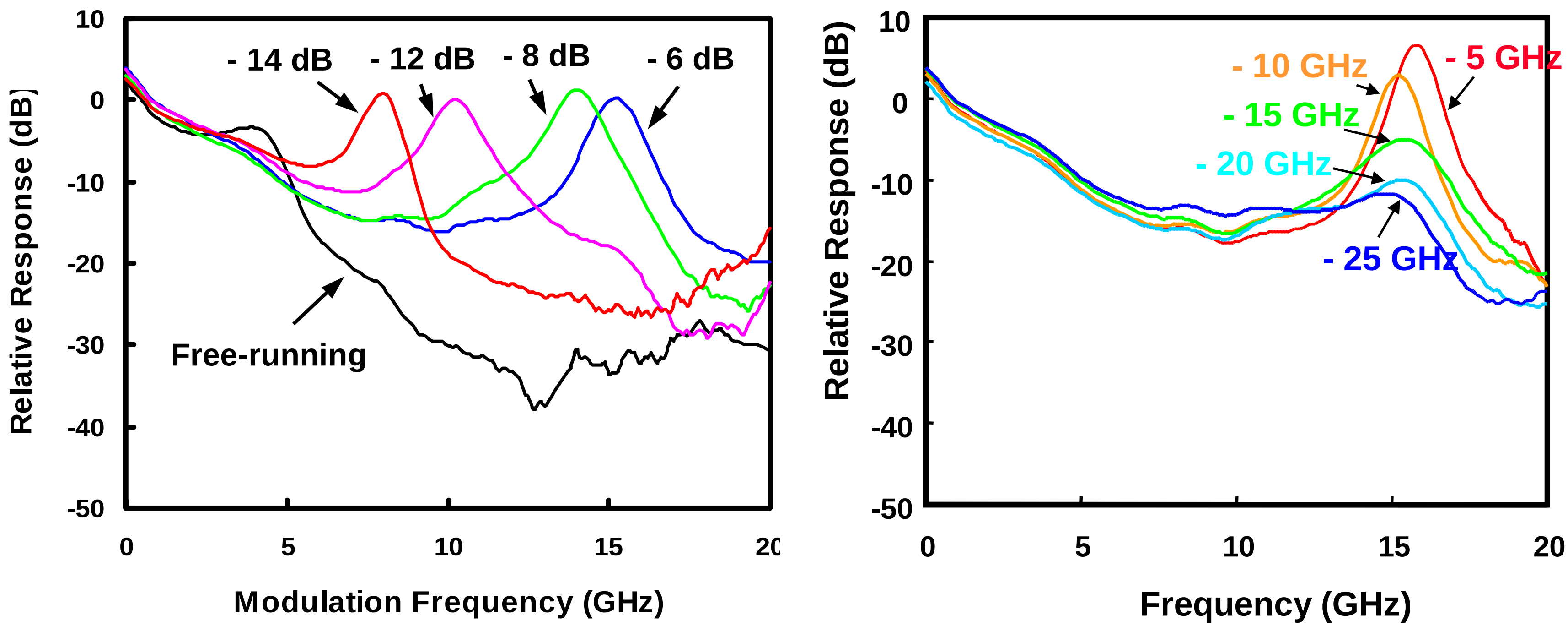
Directly Modulated RF Lightwave Transmitters

- Direct modulation of semiconductor laser
  → Compact, simple, low cost
- Disadvantages of direct modulation:
  – Low optical-RF conversion efficiency
  – Bandwidth limited by relaxation oscillation frequency
  – Large nonlinear distortion
  – Chirp
  – High RIN
- Has been primarily used in lower performance systems

Directly Modulated Transmitter with Strong Optical Injection Locking

- **Strong optical injection locking significantly enhance the performance of direct modulation:**
  - **Increase the modulation bandwidth to beyond the fundamental limit of relaxation oscillation**
  - **Reduce nonlinear distortions**
  - **Reduce RIN**
  - **Reduce chirp**
- **Enhance the modulation efficiency using gain-lever effect**

Modulation Dynamics of Directly Modulated DFB Laser with Strong Optical Injection



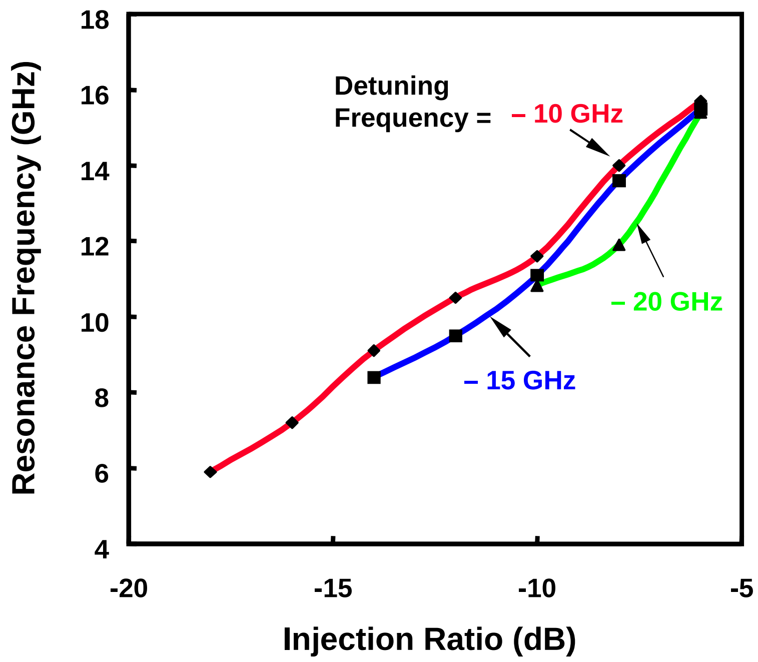
- **Enhance modulation bandwidth**
  - ***Relaxation oscillation frequency*** **increased by 4 times**
- **Resonant peak height controlled by detuning frequency**

Multiplex, Inc.
Photonics for Communications

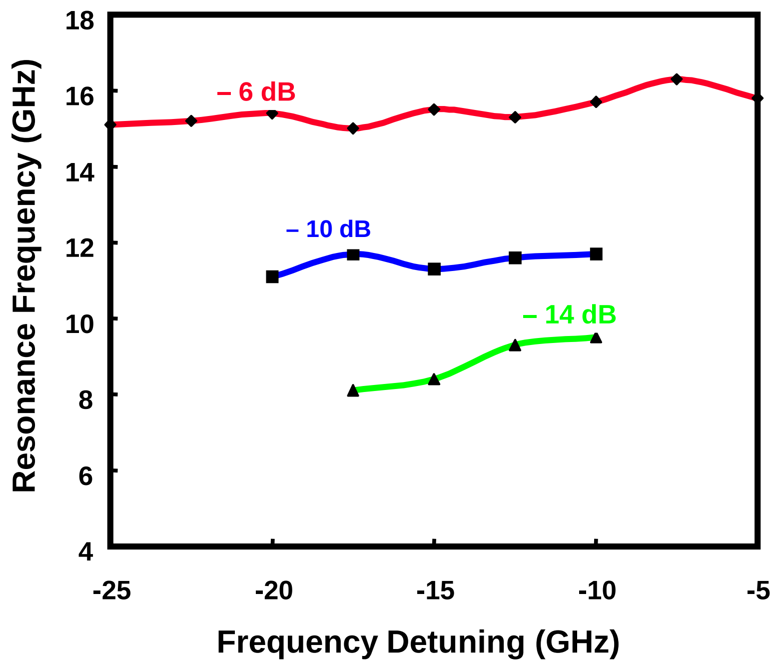
UCLA UCSD

Modulation Dynamics of Injection-Locked Semiconductor Lasers

Resonant Frequency



Peak Height of Resonant Frequency

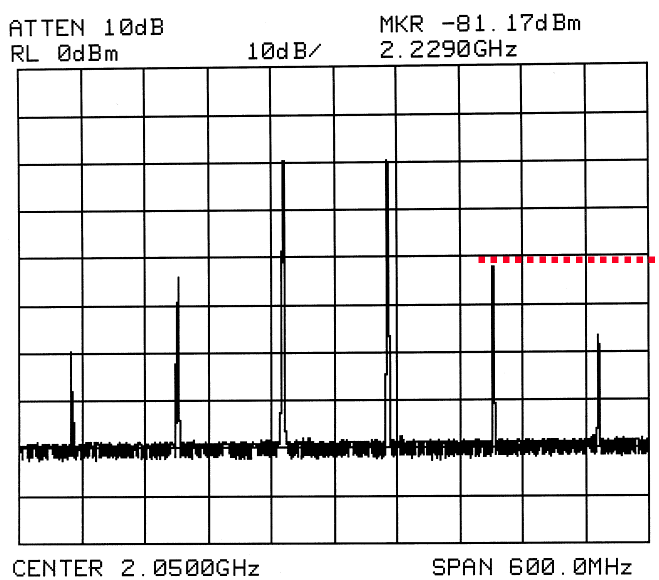


Multiplex,Inc.
Photonics for Communications

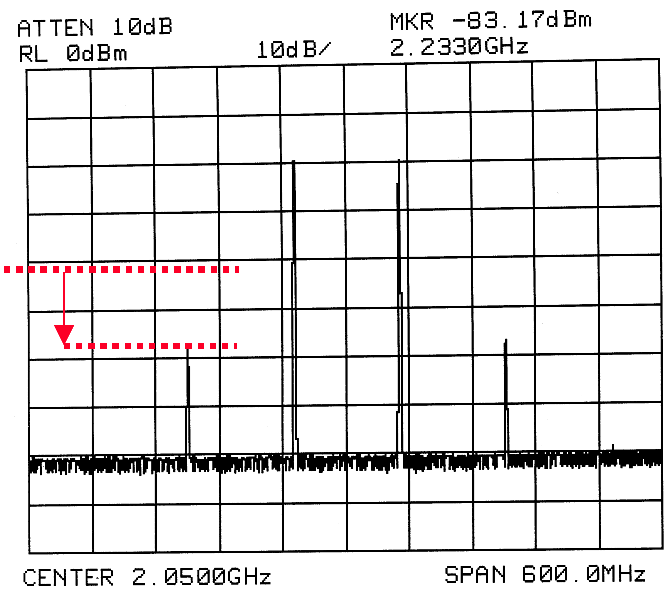
UCLA UCSD

Suppression of Nonlinear Distortions

2-Tone Modulation Test



Free Running



Injection Locked

- **Second harmonic distortion as well as third-order intermodulation distortion are reduced by 15 dB**

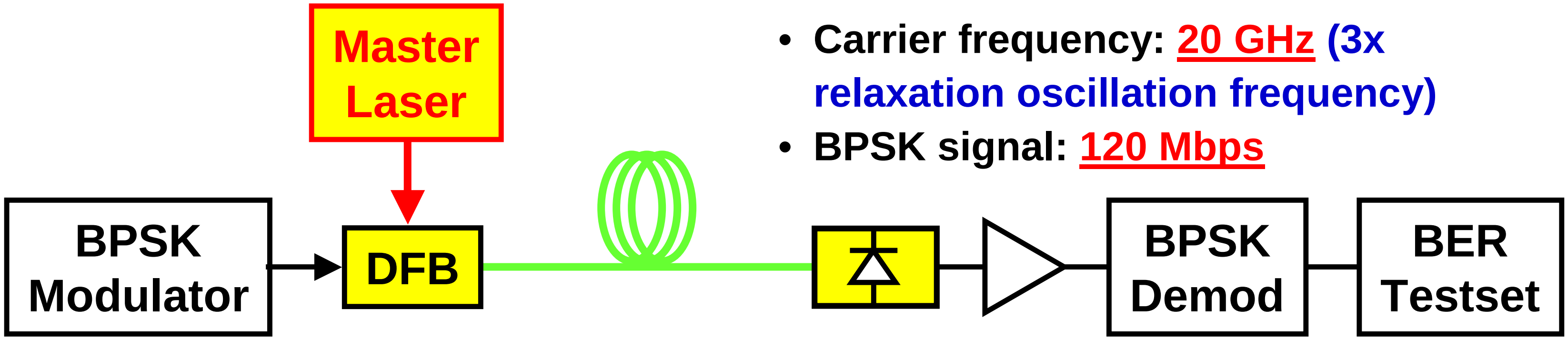
Ref: Xue, Chau, Wu, Optical Fiber Communications Conference (OFC) 1999.

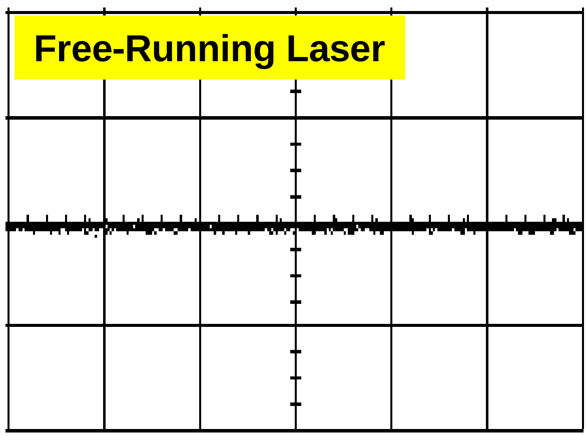
Multiplex,Inc.
Photonics for Communications

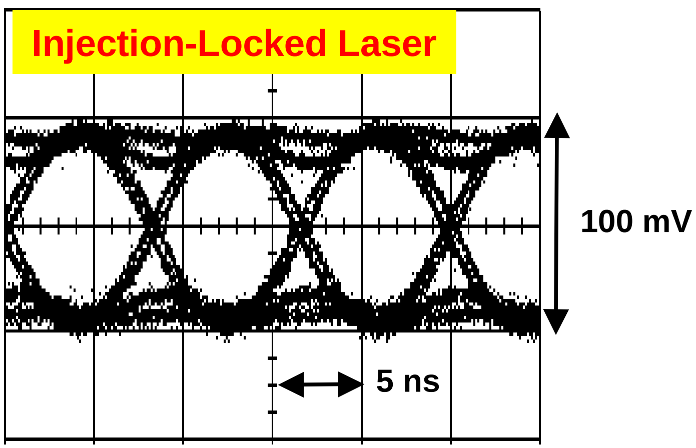
UCLA UCSD

RF Photonic Links Operating at 3x Relaxation Oscillation Frequency (20 GHz)

- Carrier frequency: 20 GHz (3x relaxation oscillation frequency)
- BPSK signal: 120 Mbps







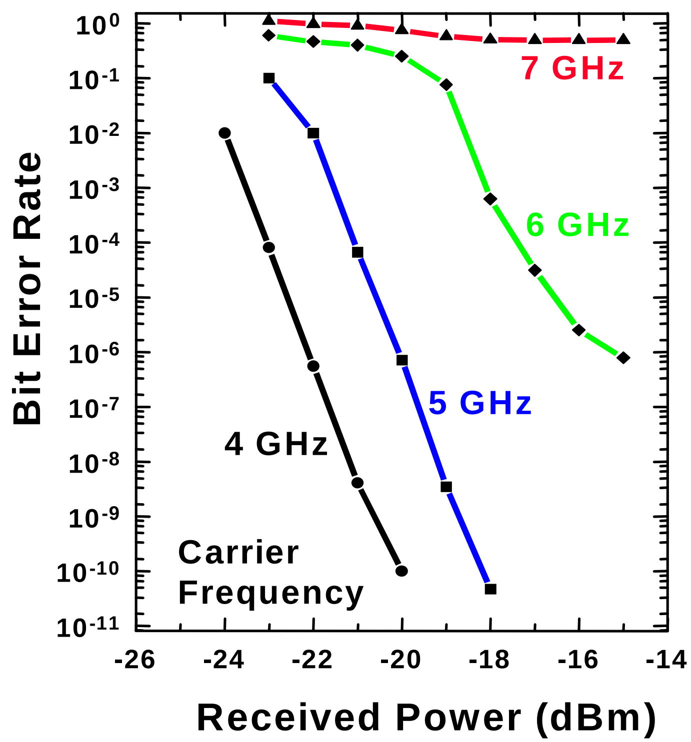
Ref: X.J. Meng, D.T.K. Tong, T. Chau, and M.C. Wu, *IEEE Photonics Technology Letters,* Vol.10, No.11, November 1998.

Multiplex,Inc.
Photonics for Communications

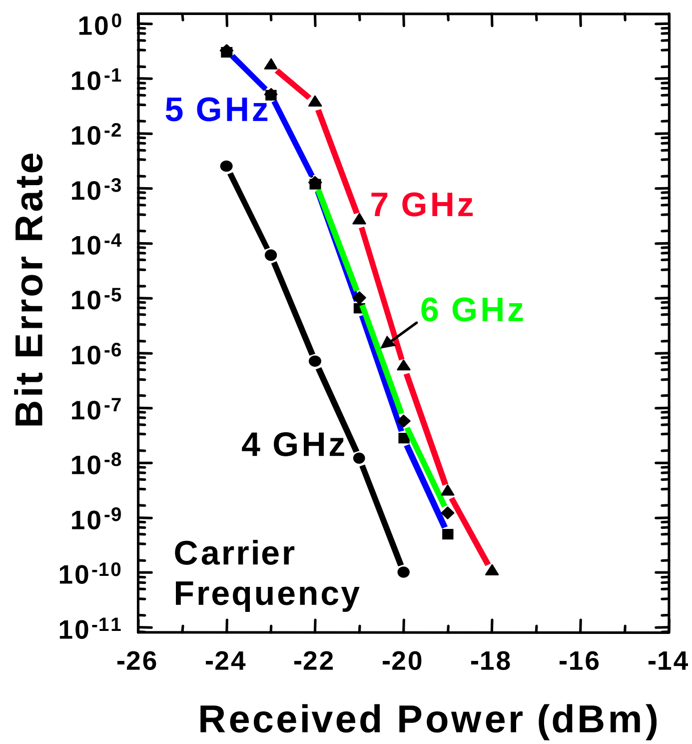
UCLA UCSD

Performance of SCM-BPSK Links with Directly Modulated Lasers

Free-Running



Injection-Locking



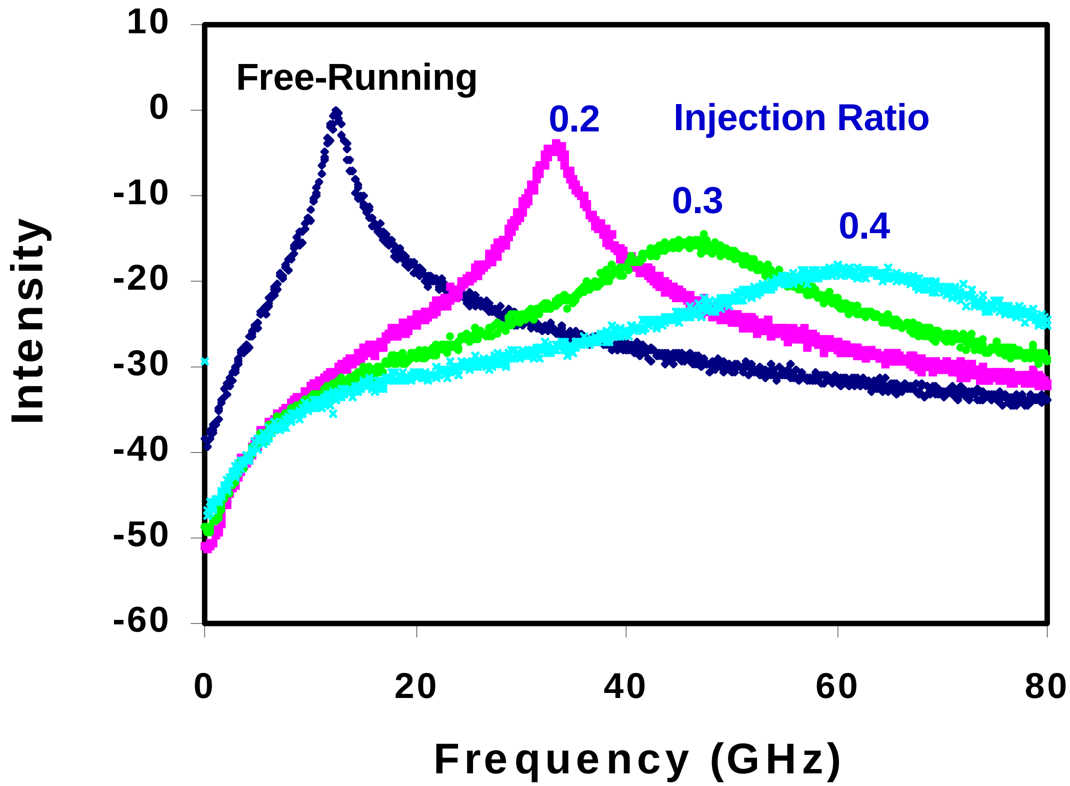
Ref. Xue, et al, IEEE PTL, 1998

PRBS Rate = 120 Mbps
Injection ratio = 0.08
Detuning frequency = - 6. 5 GHz

Multiplex,Inc.
Photonics for Communications

UCLA UCSD

Simulated RIN Noise and Relaxation Oscillation Frequency of DFB Laser with Strong Optical Injection



Preliminary simulation results indicate broadband modulation with bandwidth > 50 GHz can be achieved by strong optical injection locking

Team Management